Environmental Pollution 234 (2018) 115–126

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Airborne microplastics: Consequences to human health?☆

Joana Correia Prata

University Fernando Pessoa, Fernando Pessoa Energy, Environment and Health Research Unit (FP ENAS), Praça 9 de Abril, 349, Porto, Portugal

ARTICLE INFO

Article history:
Received 24 February 2017
Received in revised form
9 November 2017
Accepted 10 November 2017

Keywords:
Nanoplastics
Atmospheric pollutant
Particulate matter
Dust
Fibers
Toxicity

ABSTRACT

Microplastics have recently been detected in atmospheric fallout in Greater Paris. Due to their small size, they can be inhaled and may induce lesions in the respiratory system dependent on individual susceptibility and particle properties. Even though airborne microplastics are a new topic, several observational studies have reported the inhalation of plastic fibers and particles, especially in exposed workers, often coursing with dyspnea caused by airway and interstitial inflammatory responses. Even though environmental concentrations are low, susceptible individuals may be at risk of developing similar lesions. To better understand airborne microplastics risk to human health, this work summarizes current knowledge with the intention of developing awareness and future research in this area.

1. Introduction

Microplastics, plastics <5 mm, are contaminants of high concern due to the increased production and disposal of plastic products and low biodegradation rates (Andrady, 2011; Thompson, 2015). They have already been detected in water (Dris et al., 2015; Eriksen et al., 2014; Van Sebille et al., 2015), sediment (Browne et al., 2011; Frias et al., 2016) and several species of organisms (Davidson and Asch, 2011; Foekema et al., 2013; Vandermeersch et al., 2015). Microplastics may result from the fragmentation of plastic objects (secondary microplastics) (Andrady, 2011) or the release of plastic particles, such as those used in cosmetics (primary microplastics) (Browne et al., 2011). Sources of microplastics are associated with larger population densities (Browne et al., 2011), whereas distribution is influenced by currents, winds and particle density (Engler, 2012), in some cases responsible for their movement between environmental compartments (Horton et al., 2017).

Due to their small size, microplastics may interact with a wide range of organisms causing obstruction, inflammation and accumulation in organs after translocation (Wang et al., 2016; Wright et al., 2013). Microplastics have shown to reduce photosynthesis and growth in microalgae (Sjollema et al., 2016), have negative effect on the feeding activity of zooplankton (Setälä et al., 2014) and lugworms (Besseling et al., 2013), accumulate and possibly cause adverse effects to gills, stomach and hepatopancreas of crabs (Brennecke et al., 2015) and induce alterations in histology and biomarkers in fish (Karami et al., 2016). They may also be responsible for the transport of contaminants or microorganisms (Andrady, 2011; Wang et al., 2016).

Literature reviews exploring the effects of microplastics in human health focus mostly on the digestive system (see Galloway, 2015). This is natural, since the aquatic ecosystem has been the center of attention and ingestion of contaminated organisms (Vandermeersch et al., 2015) could lead to the uptake of microplastics in the human intestine (Van Cauwenberghe and Janssen, 2014). Only one review has focused on human exposure by inhalation (Wright and Kelly, 2017). One source of microplastics to the atmosphere is textiles, each garment may be responsible for the release of approximately 1900 fibers per wash (Browne et al., 2011). It is possible that these fibers are also released to the atmosphere, as microplastics sampling protocols alert for the danger of airborne contamination (Browne et al., 2011; Frias et al., 2016; ICES, 2015; Vandermeersch et al., 2015). Indeed, by using blanks or open petri dishes, some authors detected contamination of their samples or their working environments (Davidson and Asch, 2011; Foekema et al., 2013; Fries et al., 2013; Nuelle et al., 2014; Woodall et al., 2015), probably caused by airborne microplastics released from clothes. Following studies identified microplastics in the atmospheric fallout of a city (Dris et al., 2015, 2016), supporting the idea of airborne contamination.

☆ This paper has been recommended for acceptance by Eddy Y. Zeng.

E-mail address: joanacorreiaprata@gmail.com.

https://doi.org/10.1016/j.envpol.2017.11.043
0269-7491/

The present literature review will summarize the state of the knowledge on the evidences of atmospheric contamination with synthetic polymers and their fates and effects in organisms after inhalation, especially on humans, by discussing existing research regarding airborne microplastics (for simplicity this term will also include nanoplastics, plastics < 100 nm that are likely present in the air and inhaled due to their small dimensions). Five sections address exposure and health effects of airborne microplastics in the following order: (1) analysis of exposure based on concentrations and factors of distribution; (2) occupational diseases related to airborne microplastics exposure; (3) mechanisms of particle toxicity for airborne microplastics; (4) mechanisms of translocation; (5) other mechanisms of toxicity besides particle toxicity; (6) discussion of consequences to human health.

2. Concentrations and distribution of airborne microplastics

To explain the risk for human health of environmental exposure to microplastics in the atmosphere, we must first understand exposure. Therefore, we need to understand potential sources, concentrations and factors involved in the dispersion of indoor and outdoor airborne microplastics. Microplastics may also be present in unidentified fractions of particulate matter.

2.1. Sources of airborne microplastics

Environmental exposure to airborne microplastics is dependent on the wide distribution of their sources. Synthetic textiles, erosion of synthetic rubber tires, and city dust are thought to be the most important sources of primary microplastics, and wind transfer is estimated to be responsible for 7% of ocean's contamination (Boucher and Friot, 2017). Other sources of airborne microplastics may include plastic fragments from clothes and house furniture (Dris et al., 2016, 2017; Liebezeit and Liebezeit, 2015), materials in buildings, waste incineration, landfills (Dris et al., 2016), industrial emissions, particle resuspension, particles released from traffic (Dris et al., 2015), synthetic particles used in horticultural soils (e.g. polystyrene peat), sewage sludge used as fertilizer (Liebezeit and Liebezeit, 2015) and possibly tumble dryer exhaust. Forensic studies were also able to retrieve synthetic fibers from outside surfaces, car seats (Grieve and Biermann, 1997; Roux and Margot, 1997) and worn T-shirts (Marnane et al., 2006). Indeed, synthetic clothing is thought to be the main source of airborne microplastics (Dris et al., 2016), fiber material and quantity dependent on fashion and season (Roux and Margot, 1997). Therefore, synthetic textiles may be responsible for environmental exposure, in both indoor and outdoor environment.

2.2. Concentrations of airborne microplastics

There is still little information regarding concentrations of airborne microplastics. In a study carried out in Greater Paris, microplastics in atmospheric fallout were assessed using a stainless-steel funnel of known area connected to a 20 L glass bottle, retrieving concentrations of 118 microplastics m^2 day^{-1} (Dris et al., 2015) and of 110 and 53 atmospheric fallout particles m^2 day^{-1} (29% microplastics) (Dris et al., 2016). This high variability is probably dependent on climate conditions and seasonality, but also on sampling methodology. Synthetic fibers were also found in flowering plants, most likely contaminated from atmospheric fallout (Liebezeit and Liebezeit, 2015). Indoor air concentrations have been found to be in the 3 to 15 particles m^{-3} range (Gasperi et al., 2015). A recent study in Paris also evaluated the indoor (0.4–59.5 particles m^{-3}, 33.3% containing polymers) and outdoor (0.3–1.5 particles m^{-3}) fiber concentration, revealing that the distribution pattern points to the presence of numerous inhalable fibers below their detection limit of 50 μm (Dris et al., 2017). Moreover, present knowledge on atmospheric microplastics concentrations is restricted by detection limits and identification of polymeric particles. Exposure to higher concentrations seem to occur in indoor environments, probably due to sources and factors involved in the dispersal of particles.

2.3. Fate and dispersion of airborne microplastics

The fate and dispersion of microplastics in indoor and outdoor environments are dependent on several factors, influencing human exposure. Factors affecting microplastics behavior and transport in the atmosphere may also be analogous to those of particulate matter, namely: (a) vertical pollution concentration gradient (higher concentrations near the ground); (b) wind speed (increase in wind speed results in decrease in concentration); (c) wind direction (parallel *versus* perpendicular to obstacles); (d) precipitation (affecting in particles larger than 2.5 μm); and (e) temperature (lower temperatures increase nucleation and condensation resulting in lower atmospheric concentration) (Kaur et al., 2007). Additionally, distribution of air contaminants in outdoor urban environments may result from wind modulation caused by urban topography (e.g. space between buildings), local meteorology and thermal circulation (heat islands perturbing air flow) (Fernando et al., 2001). Particle residence time in the atmosphere and subsequent atmospheric fallout is influenced by rainfall, wind, local conditions and particle size, resulting in sedimentation by gravity of larger particles or after nucleation (Dris et al., 2015; Perrino, 2010). Polymers of lower densities are lighter and can be carried by the wind, further contaminating the terrestrial and aquatic environments (Horton et al., 2017; Nizzetto et al., 2016). Therefore, human exposure to atmospheric microplastics is dependent on sources and influenced by meteorological and geographical factors. Exposure to low concentrations of airborne microplastics is expected in outdoor air due to dilution (Dris et al., 2017). However, in adverse atmospheric conditions (e.g. low wind speed) the removal of microplastics may be reduced resulting in exposure to higher concentrations.

Higher concentrations of airborne microplastics have been found indoors, as stated in Section 1.2., probably due to the release of particles by indoor sources and lower removal by dispersal mechanisms. Indoor behavior of airborne microplastics behavior is dependent on room partition, ventilation and airflow, resulting in higher concentrations in rooms downwind (Alzona et al., 1979). Airborne nanoparticles (<100 nm), like nanoplastics, will rapidly diffuse between compartments and remain airborne (Seaton et al., 2009). Since most sources of fine particulate matter (Chang et al., 2006) and microplastics (Dris et al., 2017) seem to be indoors and people spend an average of 70–90% of their time inside (Alzona et al., 1979) it follows that indoor exposure to airborne microplastics appears to be more relevant. It is likely that effects on human health result more often from occupational exposure than from exposure at home. Inadequate conditions in factories working with high volumes of polymeric materials, such as lack of efficient ventilation, may result in chronic exposure to high concentration of airborne microplastics. Furthermore, microplastics generated indoors may contaminate the outside air, where they are diluted in the atmosphere resulting in lower concentrations (Dris et al., 2017), while only 30% of outdoor particulate matter is able to penetrate indoors in a closed room (Alzona et al., 1979). This illustrates the importance of indoor air as a source and as the main place of exposure to airborne microplastics.